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THE POTENTIAL OF WAVE AND OFFSHORE WIND ENERGY IN AROUND THE COASTLINE OF MALAYSIA THAT FACE THE SOUTH CHINA SEA

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ABSTRACT

The world wide estimated wave energy resource is more than 2 TW. Offshore wind speeds are generally higher than wind speeds over land, hence higher available energy resource. The estimated offshore wind potential in European waters alone is in excess of 2500 TWh/annum. Offshore area also provides larger area for deploying wind energy devices. In recent year efforts to promote these two types of renewable and green energy sources have been intensify. Using the data obtained from the Malaysia Meteorological Service (MMS) analysis was conducted for the potential of wave energy and wind energy along the coastline of Malaysia facing the South China Sea. Maps of wave power potential were produced. The mean vector wind speed and direction were tabulated.

Keywords: wave energy; Malaysia; South China Sea; wind

INTRODUCTION

In recent times, adoption of renewable and clean sources of energy has gained ground around the world. Ocean waves and wind are types of energy that is clean and renewable. The worldwide estimated wave energy resource is more than 2TW and the estimated offshore wind potential in European waters alone is in excess of 2500 TWh/annum. The average wave energy flux worldwide is of the order of several to a few tens of kilowatts per meter of shoreline (kW/m).

The development of wind farms is concentrated in Europe with Denmark, United Kingdom and Germany among the leaders in this field. Utilisation of ocean waves energy is still mainly in the stage of research and development. These R&D developments are mainly concentrated in countries such as United Kingdom, Norway, Denmark, Japan, China, India, United States and Australia (Hagerman, 2001). A review summarising the status of wave energy conversion technologies was published by A. Clement and et al. (2002).

This paper present a summarised wave power potential and corresponding wind speed for locations in Malaysia coastline that face the South China Sea.

METHODS

The data for the ocean waves and wind climatology is extracted from the Monthly Summary of Marine Meteorological Observations by the Malaysian Meteorological Service (MMS). The available data covered the period of 1985 to 2000. The data is grouped in a 2 degree by 2 degree square and given a set of monthly statistical data for each square. The wave statistical data is separated into two groups, wind waves and swell. The wave characteristics that were used are maximum wave height / period / direction and average wave height / period / number of observations for wind waves and swell accordingly. The wind characteristics that were used are the vector resultant wind direction, vector resultant wind speed and number of observations.

For this paper, only coastline of Malaysia that faces that South China Sea is considered. Figure 1 shows the study locations. Numbers 1 to 10 were assigned to each location. Grids 1, 2 and 3 represent area covering the east peninsular Malaysia coastline that faces east of South China Sea. Grids 4, 5, 6, 7, 8, 9 and 10 represent area covering the north-west side of Borneo that forms part of Sarawak and Sabah coastline.

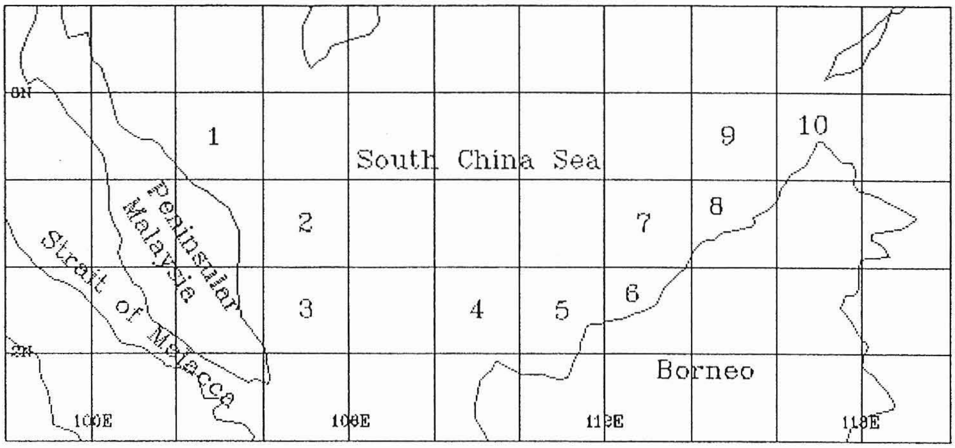


FIGURE 1 Study location sites.

The data were keyed into the computer for analysis. The average wave height in meter (H_a) and average wave period in second (T_a) were used to calculate the wave energy flux or wave power (P in kW/m) according to the following equation:

$$P = 0.5 \times (H_a)^2 \times T_a$$

The multiplier of 0.5 in the above equation depends on the shape of the wave spectrum, which can range from 0.45 to 0.65 depending upon the spectral shape. The value of 0.5 in this case, is an appropriately conservative approximation. The mean wave direction was also calculated based on unit vector method. The mean vector wind direction (D in degree) and speed (V_R in knots) were calculated using unit vector method.

RESULTS AND DISCUSSION

Figure 2 shows the annual wave power and mean wave direction contributed by wind waves. Figure 3 shows the annual wave power and mean wave direction contributed by swell. From the two figures, the general annual wave power level is around 1.5 to 2.0 kW/m from wind waves and 4.0 kW/m from swell. Figure 3 shows that the coastline facing the South China Sea receive quite a bit of swell energy generated in the South China Sea that travel toward the coastline.

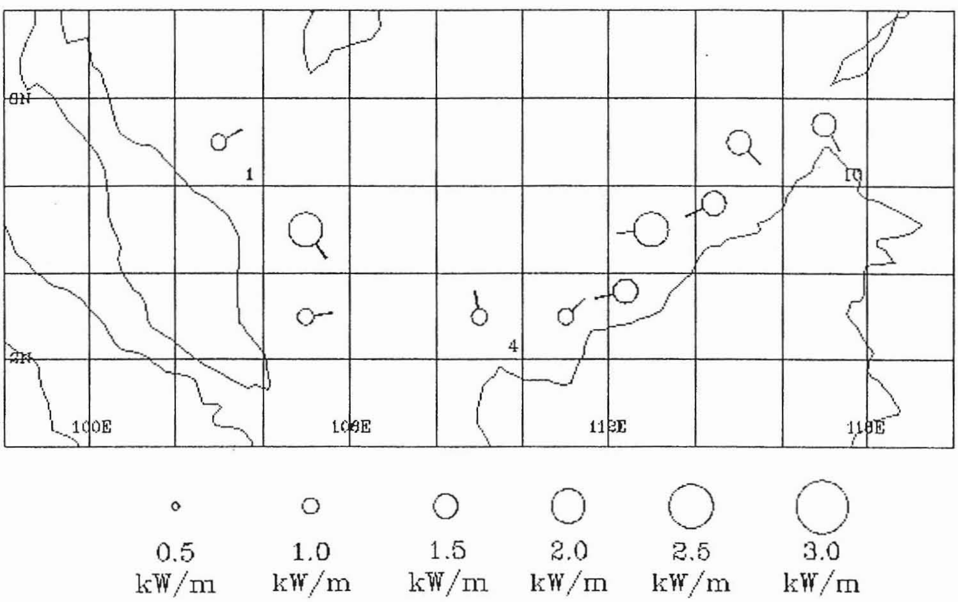


FIGURE 2 Annual wind wave power.

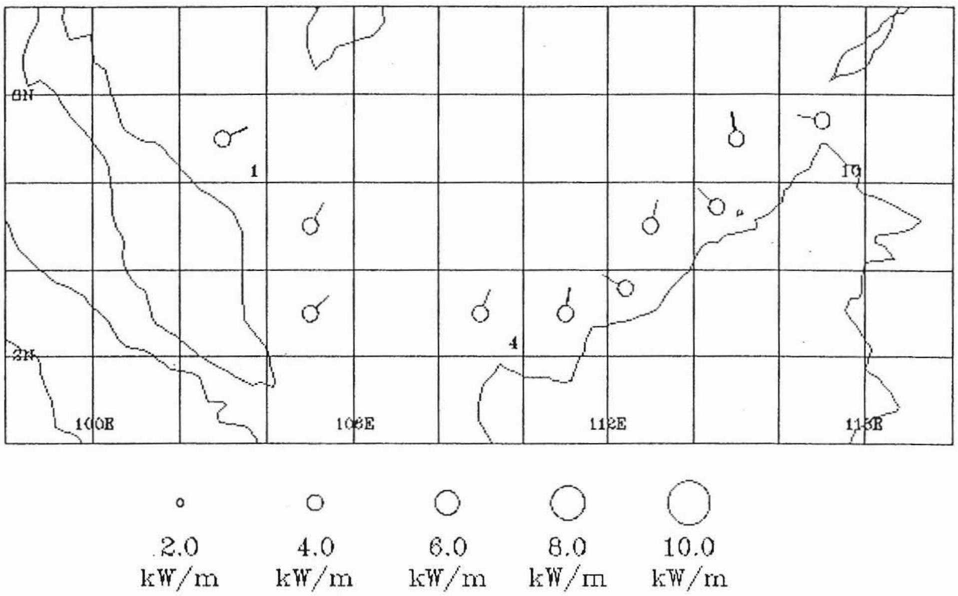


FIGURE 3 Annual swell wave power.

Figure 4 and figure 5 show the wave power level during the north-east monsoon season (November to March) for wind waves and swell respectively. From figure 4, it is seen that wave power differs for different locations and the wind wave direction is predominantly from north-east. Location 7 has the highest wave power level of 3.5 kW/m and locations 3, 4 and 5 have the lowest wave power level of 1.5 kW/m. Figure 5 shows that during the north-east monsoon season, the general swell wave power level is around 6.0 kW/m and the swell is predominately from north-east.

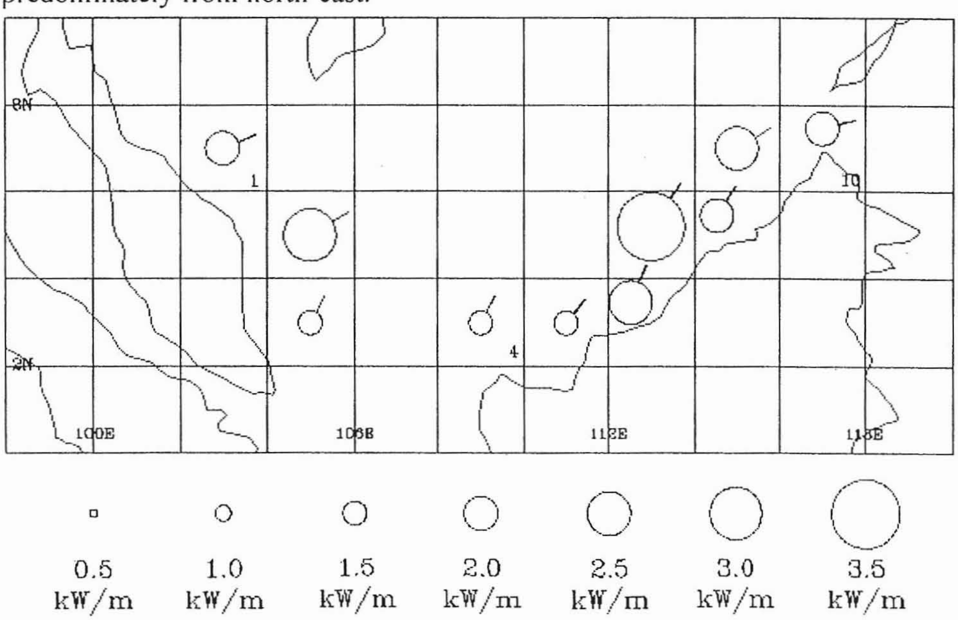
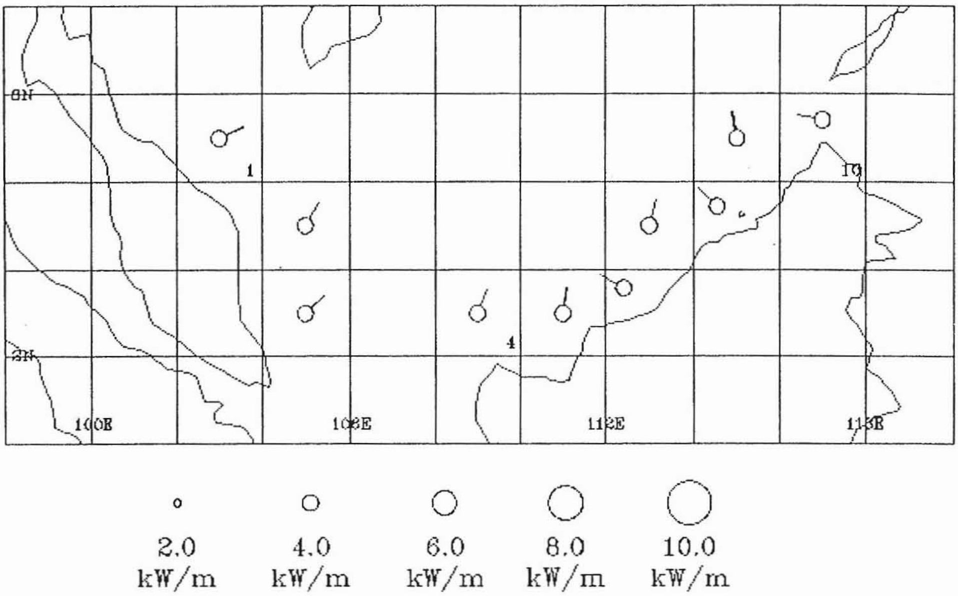


FIGURE 4 Wind wave power level during north-east monsoon season.



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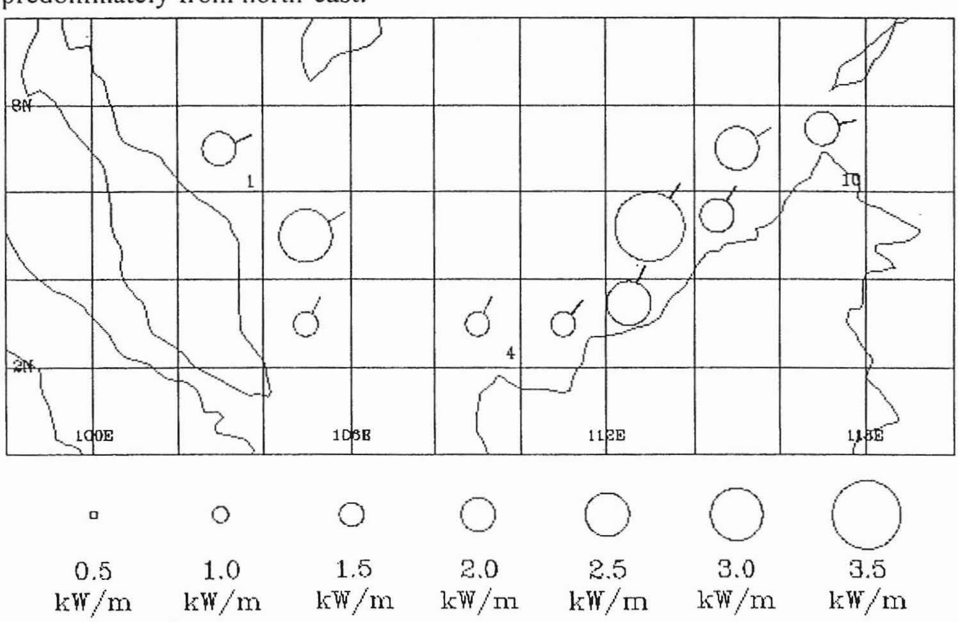

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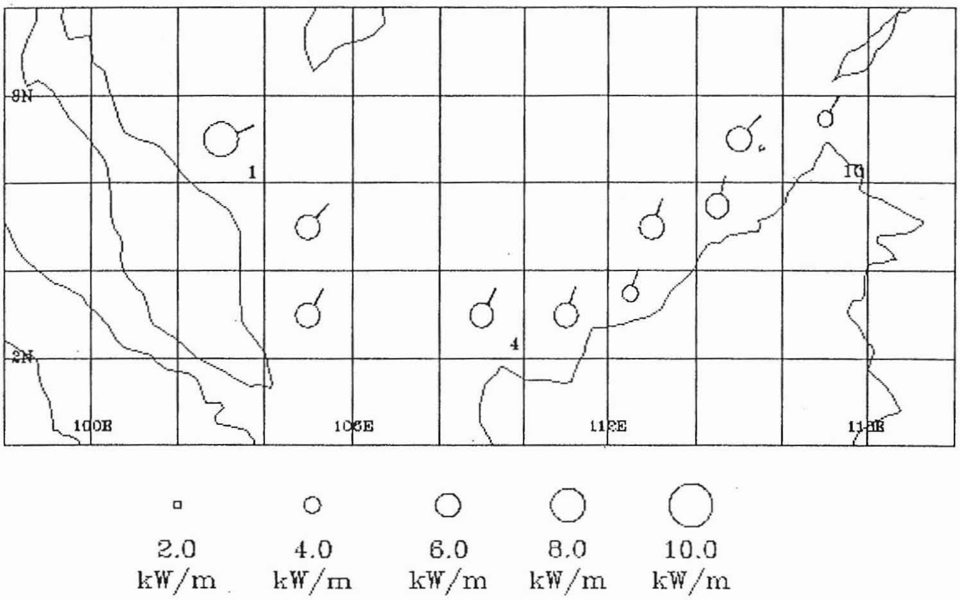

FIGURE 5 Swell wave power level during north-east monsoon season.

Figure 6 and figure 7 show the wave power level during the south-west monsoon season (May to September) for wind waves and swell respectively. Comparing figures 4 and 6, it is seen that the available wave power during the south-west monsoon season is lower than north-east monsoon season by 1.0 to 2.0 kW/m. The wave direction is predominately coming from the south-west. Figure 7 also shows that the swell wave power during the south-west monsoon season is relatively low when compared to swell wave power during north-east monsoon season. The swell wave power during these times of the year is around 2.0 kW/m and the swell direction is predominately from south-west. Stretches of Sabah coastline at locations 8, 9, and 10 shows higher swell wave power of 4.0 kW/m.

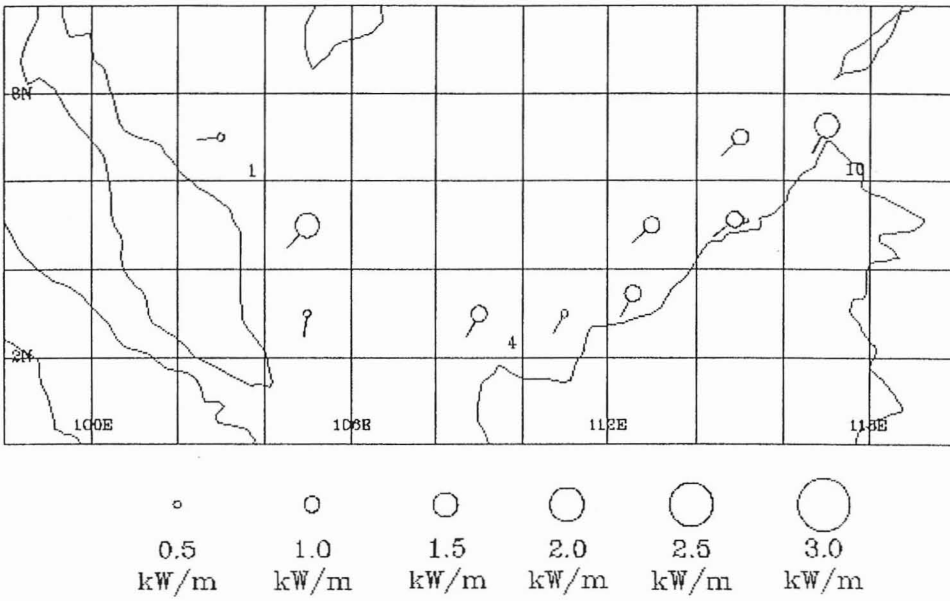

FIGURE 6 Wind wave power level during south-west monsoon season.

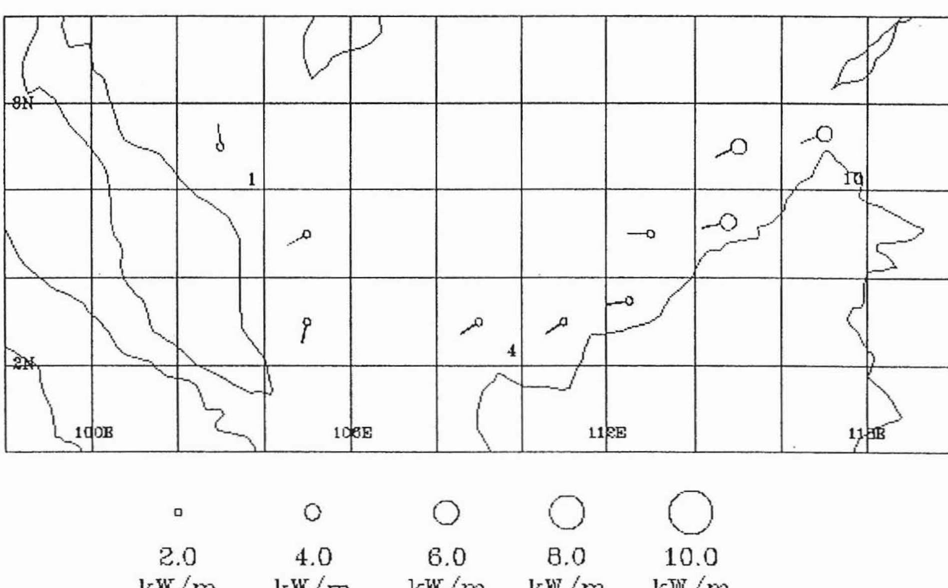

FIGURE 7 Swell wave power level during south-west monsoon season.

Table 1 shows the analysis for annual mean vector wind speed and direction and also for mean vector wind speed during two different seasons – the north-east monsoon and the south-west monsoon. From table 1, it is seen that the mean vector wind speed during the north-east monsoon season is higher. The direction of the wind also changes from north-east during the north-east monsoon season to south-west during the south-west monsoon season. The mean vector wind speed for locations situated nearer the equator shows more consistency throughout the year. The general mean vector wind speed is below 5 knot for all locations.

	Annual Mean Vector Wind		North-East Monsoon (Nov-March) Mean Vector Wind		South-West Monsoon (May-Sep) Mean Vector Wind	
	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)	Direction (degrees)	Speed (knots)
1	89	4	76	5	227	1
2	113	2	71	4	221	3
3	64	2	27	4	186	3
4	15	1	23	3	204	2
5	7	1	25	2	229	1
6	320	1	3	1	235	1
7	344	1	28	2	236	1
12	338	1	28	2	234	1
9	59	2	52	4	228	2
10	127	1	74	2	227	2

TABLE 1 Mean vector wind direction and speed.

CONCLUSIONS

The wave power around the coastline of Malaysia that faces South China Sea has been calculated and used to build a map of wave power potential. Additional analysis was done to divide the wave power potential to two seasons– north-east monsoon season and south-west monsoon season. The corresponding vector wind speed and directions were also analyzed. From the analysis, the highest annual wave power available around the Malaysian coastline that faces South China Sea is in the order of 2.5 kW/m from wind wave and 4.0 kW/m from swell. Meanwhile, the annual mean vector wind speed is in the order of 1 to 2 knots.

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REFERENCES

Baba, M. 1988. Wave power potential of Lakshadweep and Andaman & Nicorbar islands. *Indian Journal of Marine Sciences*, **17**, pp 330-332.

Chiang, E.P., Zainal, Z.A., Aswatha Narayana, P.A. and Seetharamu, K.N. 2003. Potentail of Renewable Wave and Offshore Wind Energy Sources in Malaysia. *Marine Technology 2003*.

Clement, A., McCullen, P., Falcao, A., Fiorentino, A., Gardner, F., Hammarlund, K., Lemonis, G., Lewis, T., Nielsen, K., Petroncini, S., Pontes, M.T., Schild, P., Sjostrom, B., Sorensen, H.S., and Thorpe, T. 2002. Wave energy in Europe: current status and perspectives. *Renewable & Sustainable Energy Reviews*, **6**, (2002) 405-431.

Hagerman, G. 2001. Sourthen New England wave energy resource potential. *Building Energy 2001*.

MMS. 1985-2000. Monthly summary of marine meteorological observations. *Malaysian Meteorological Service*.

Shaw, R. 1982. Wave energy: A design challenge. Ellis Horwood, Chischester.

REFERENCES

Baba, M. 1988. Wave power potential of Lakshadweep and Andaman & Nicorbar islands. *Indian Journal of Marine Sciences*, **17**, pp 330-332.

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MMS. 1985-2000. Monthly summary of marine meteorological observations. *Malaysian Meteorological Service*.

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REFERENCES

Baba, M. 1988. Wave power potential of Lakshadweep and Andaman & Nicorbar islands. *Indian Journal of Marine Sciences*, **17**, pp 330-332.

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Hagerman, G. 2001. Sourthen New England wave energy resource potential. *Building Energy 2001*.

MMS. 1985-2000. Monthly summary of marine meteorological observations. *Malaysian Meteorological Service*.

Shaw, R. 1982. Wave energy: A design challenge. Ellis Horwood, Chischester.